RFP-1325.02 (REV. 2/97)
Previously RF-46522

CORRES. CONTROL
INCOMING LTR NO.

00477 RF 97

DUE DATE

ACTION

| DIST. | LTR | ENC |
|---|---|---|
| BACON, R.F. | | |
| BENSUSSEN, S.J. | | |
| BRAILSFORD, M.D | | |
| BUHL, T.R. | | |
| BURDGE, L | | |
| CARD, R.G. | | |
| COSGROVE, M. M., | | |
| COULTER, W.L. | | |
| DERBY, S. | | |
| DIETERLE, S.E. | | |
| FERRERA, D.W. | | |
| GERMAIN, A.L. | | |
| HARDING, W.A. | | |
| HARROUN, W.P. | | |
| HEDAHL, T.G. | | |
| HERRING, C.L. | | |
| HILL, J.A. | | |
| MARTINEZ, L.A. | | |
| McANALLY, J.L. | | |
| NORTH, K. | X | |
| OGG, R.N. | | |
| PARKER, A. | | |
| PHILLIPS, F.J. | X | |
| RHOADES, D.W. | | |
| RUSCITTO, D.G. | | |
| SANDLIN, N.B. | | |
| SPEARS, M.S. | | |
| TILLER, R. E. | | |
| TUOR, N.R. | | |
| VOORHEIS, G.M. | | |
| Setlock, G. | X | |
| Shelton, D. | X | |
| Brooks, L. | X | |
| Law, J. | X | |
| Singer, S. | X | |
| Cypher, N. | X | |
| COR. CONTROL | X | X |
| ADMIN. RECORD | X | |
| PATS/T130G | | |

Reviewed for Addressee
Corres. Control RFP
4/7/97
Date By

Ref Ltr. #

DOE ORDER # 5400.1

**Department of Energy**

ROCKY FLATS FIELD OFFICE
P.O. BOX 928
GOLDEN, COLORADO 80402-0928

97-DOE-05207

APR 3 1997

Mr. Steve Tarlton
Manager, Rocky Flats Program
Colorado Department of Public Health and Environment
4300 Cherry Creek Drive South
Denver, Colorado 80222-1530

Mr. Tim Rehder
U.S. Environmental Protection Agency, Region VIII
999 18th Street, Suite 500, 8EPR-FT
Denver, Colorado 80202-2405

Gentlemen:

The enclosed memorandum is a response to CDPHE comments on the December 5, 1996, version of the IMP, groundwater section, which was delivered to DOE on January 29, 1997. Please review these responses and communicate any issues that are still outstanding. A meeting will be held soon to resolve any issues and to propose the evaluations that are planned for groundwater.

Please contact me at 966-4839 or Purna Halder at 966-9728 if you have any questions.

Sincerely,

Steven W. Slaten
Steven W. Slaten
RFCA Project Coordinator

Enclosure

cc w/o enc:
G. Kleeman, EPA
E. Pottorff, CDPHE
E. Ethington, CDPHE
J. Legare, AMEC, RFFO
B. April, DAMEC, RFFO
G. Hill, RLG, RFFO
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G. Setlock, K-H
D. Shelton, K-H
L. Brooks, K-H
J. Law, RMRS
S. Singer, RMRS
N. Cypher, RMRS
Adminstrative Record

ADMIN RECORD

A-SW-002363

Rocky Flats Environmental Technology Site
Responses to Colorado Department of Public Health and Environment Comments Received 1/29/97

Substantive comments

***(1) P.59: Several bullets could be added to this list of activities supported by monitoring data.***

- ***support estimation of contaminant fluxes***
- ***monitoring water levels***
- ***support modeling of impact to surface water***

Comment Response (Sec 4.2):

The first two bullets are too specific to be added to the list. The first of these is a specific calculation while the second is a specific measurement. This section is trying to outline larger processes that the groundwater program is supporting rather than the types of data that are used in that process. The third bullet has been added to the list and is briefly described in a section that has been added. As with the rest of the document, the term "evaluate" has been used instead of "model" to allow for field investigations as well as modelling.

***(2) P.65, 4.2.3: Add concept of collecting recharge and discharge data.***

Comment Response (Sec. 4.2.3):

This comment involves the addition of wording in the section on contaminant pathways to add the collection of "recharge and discharge data". The text has been amended to acknowledge the fact that water level data can help estimate recharge and discharge, but there are no plans to collect actual recharge or discharge data for groundwater on a routine basis. A brief review paper has been included which discusses the problems associated with determining recharge and discharge at the Site.

***(3) P.66: Ground water monitoring below the ITS - all wells remaining in the monitoring program are in the N. Walnut Creek alluvium and are more likely to monitor a plume created before ITS than detect contaminants not collected by the system. Also, there may be other sources of contamination in that drainage.***

Comment Response (Sec 4.2.5):

This comment suggests that the wells used below the ITS are alluvial wells in the N. North Walnut Cr. ( e.g. B208789, 1786) drainage and may be detecting upstream contamination as opposed to contamination coming downgradient from the ITS. The spatial distribution of the nitrate plume, as depicted on recent plume maps clearly shows the nitrate source to be in the vicinity of the Solar Ponds. The wells in the monitoring program were chosen with reference to this nitrate plume and show nitrate concentrations above 10 Mg/L in the N. Walnut drainage. Wells on the hillside west of the Solar Ponds (e.g. P219189 and 22796) do not show elevated nitrate concentrations. This suggests that the wells in the N. Walnut Cr. drainage are detecting contaminants coming downgradient from the Solar Ponds in the vicinity of the ITS.

***(4) P.70: If contamination reaches drainage wells they fall under the same requirements as Tier II wells.***

Comment Response (Sec 4.3.2):

As with the rest of this document, the term "plume extent well" has been used to include the larger group of wells that are used to monitor contaminant migration as opposed to the small list of wells cited in the RFCA Action Level Framework Document. Since Tier II wells are considered a subset of the plume extent wells and since the actions taken would be the same, the text will remain as currently written. In the IMP, the terms Tier I and Tier II are considered exdeedance levels as opposed to well types.

***(5) Boundary wells monitor the quality, not impact. Not all ground water leaving the Site is in the stream alluvium. Wells 0386, 6491, and 41591 are in the drainage but in lithologies other than alluvium.***

Comment Response (Sec 4.3.2):

We agree that quality is a better term than impact in this paragraph on the boundary wells. We also agree that some boundary wells are screened in other materials. The text has been changed to reflect this.

***(6) Where are the D&D wells going to be specified:***

Comment Response (Sec 4.3.2):

Historically, wells have been installed per the guidance in the Final IM/IRA Implementation Plan for the Industrial Area. Five of the eleven wells proposed in this document were installed in FY96. They are wells 22596 - 22996. Because four of the wells chosen also met the 'Plume Extent well' criteria during the ongoing DQO process and because D&D schedules had not been finalized for the nearby buildings, they were renamed as plume extent wells. The fifth well (22996) has retained the D&D designator because it did not fit other DQO criteria and because Bldg. 886 is scheduled for D&D in FY97. Much of the groundwater portion of the IM/IRA scope has been incorporated into the Building D&D decision in the IMP.

At present, there are two documents that will contain information on proposed D&D wells at RFETS. The Industrial Area IM/IRA Final Report will serve as a vehicle for presenting any proposed D&D monitoring activities for groundwater. The RFCA final report will include information on any new activities that will involve D&D monitoring for groundwater. The IM/IRA groundwater program will be integrated with the RFCA groundwater program in future years and will have one point of contact for D&D and the other groundwater decisions.

***(7) P.71: Last paragraph is out of date, RFCA is in force, the standards approved.***

Comment Response (Sec 4.3.2):

This sentence was changed in the last revision.

*(8) P.72: Why is the added language about comparison to historic data necessary or relevant. Revise comparison to background to be consistent with Implementation Guidance Document which states the M2SD. Change 100x to Tier I. It is time to be more specific about which program is responsible for conducting the evaluation of impact to surface water.*

Comment Response (Sec 4.3.2.1):

This is the first of a number of questions/objections to the comparison to historic levels in the IMP decisions. Wells in the monitoring network were generally chosen with reference to specific criteria:

- Spatial location with respect to known contaminant plumes. In most respects this has meant VOC contaminant plumes, because they are considered the most important contaminant in groundwater
- A pathway to surface water
- Using pre-existing wells where possible to be cost effective

Most of the plume definition wells are already above the Tier II action level and, based on historic data, may already be known to be above the Tier I action level for some non-VOC chemicals. A similar scenario exists for some plume extent wells. The reason for this is that great emphasis was placed on choosing wells with respect to the known VOC plumes and did not take all analytes into account for well placement. Given that fact it is not unexpected that other compounds may show up other than VOCs that are above Tier I or Tier II levels. This raises the question of how the Site can set up a valid monitoring network for organic contamination while accommodating exceedances of other analytes with lesser health risks.

Under the IMP, an exceedance in a plume extent well automatically triggers three monthly rounds of sampling. In an attempt to limit monthly sampling for exceedances that have been historically documented, the concept of using the mean plus 2 standard deviations was proposed in the October 16th meeting of the groundwater workgroup. This means that where monitoring wells are being used in areas with historic problems, the exceedances that will be detected in future monitoring will be compared to levels already documented in the historic data to detect abnormal increases in concentration. The Mean + 2 standard deviations is the statistic that is proposed to determine whether concentrations are anomalous with respect to the historic data for that well. The IMP proposes that the historic data set will be groundwater data from 1991 up to October 1, 1996. This data set is believed to be a good representative sample of the water quality data from RFETS wells.

Groundwater Conceptual Plan discusses the historically known groundwater contamination and has established a priority for dealing with these historic problems. The function of the IMP is not to continuously alert stakeholders to known problems but to alert stakeholders to new or different groundwater problems. An alternative approach would be to consider only data collected since the approval of RFCA in July, 1996. If an exceedance is detected with respect to Tier II levels in monitoring results, historic data for that well will be looked at to see if there is an historic baseline of contamination for this compound. If the answer is yes, then a check will be made to see if the area has received an evaluation of impacts to surface water. If not, then the area of exceedance will be appropriately prioritized for evaluation. If there is no historic baseline for the compound above action levels, then monthly sampling would be done if it is a plume extent, drainage or boundary well. Monthly sampling would also be done if an historically high compound has exceeded the mean plus 2 standard deviations for historic data.

This updated decision rule for plume extent, drainage and boundary wells would be described as follows:

IF Concentrations are > Tier II Action Levels

AND Concentrations are > background mean + 2 standard deviations

THEN Report as a Tier II exceedance and review historic data for well and determine if evaluation of surface water impact has been done

IF Historic data confirms exceedance and evaluation has not been done

THEN Evaluate impact to surface water

IF Concentrations for a known contaminant are greater than the mean + 2 standard deviations with respect to historic baseline

OR Historic exceedances have not been documented

THEN Initiate monthly sampling for three months

IF Monthly sampling confirms an exceedance

THEN Notify appropriate parties and evaluate impacts to surface water

ELSE Continue monitoring

For the Plume Definition Wells the following logic would apply:

IF Concentrations are > Tier I Action Levels

AND Concentrations are > background mean plus 2 standard deviations

THEN Report as a Tier I exceedance, review historic data for well and determine if area has been prioritized for remediation/evaluation based on potential impact to surface water

IF Data shows a non-decreasing or increasing trend over a two year period or has not been previously prioritized for remediation.

THEN Update priority for remediation

ELSE Continue monitoring

The use of the background UTL in the decision logic has been changed to reflect the decision to use the mean plus 2 standard deviations column from the 1993 Background Characterization Report, rather than the UTL column from this report. The text has been updated to reflect this. Also, the change from 100 x MCL has already been changed in the last revision.

The comment also questions which program is responsible for the evaluations that would be done in response to exceedances of action levels. This specific information was intentionally left out of the decision rules so that they would not need to be re-written every time there is a reorganization at RFETS. The ER program at RFETS is at present responsible for the data collection, evaluation and remediation of all outside building problems. Within ER, the Water Management and Treatment Group is responsible for monitoring and evaluations, while the Accelerated Actions group is responsible for active remediation of a site. An organization chart will be included in the final document that will outline the responsible organizations.

***(9) Contamination in a plume extent or Tier II well indicates a need for an evaluation of impact to surface water but does not need to trigger monthly sampling. Name the appropriate parties.***

Comment Response (Sec 4.3.2.2):

The discussion in Comment #8 addresses the same issue as is being questioned here.

This comment also requests to know who the appropriate parties are for reporting and notification purposes. This information was intentionally kept general in the decision logic. However, reference has now been made to the appropriate parties in the implementation portion of the document in section 4.5.1.3. At present, the known 'parties' are CDPHE and EPA for groundwater issues as these two groups are signatories to the RFCA Agreement. In addition, public presentation of the quarterly groundwater information in support of RFCA is planned as part of the State Exchange meetings, which are already established.

***(10) P.76: If a drainage well has historic contamination an evaluation of contaminant loading to surface water should be done if action levels are exceeded. See comment above, monthly samples may not be necessary to confirm exceedance. Action level is Tier II not I.***

Comment Response (Sec 4.3.2.3):

The comment for this section is the same as those raised in Comments 8 & 9 above. The typographical error (i.e. Tier I) in the decision logic was already fixed in the last revision.

***(11) P.78: See Comment Response 2 for P.70. Name appropriate parties, Cities?***

Comment Response: Please refer to Comment Response #2 and Comment Response #9.

***(12) P.80: A reference needs to be made to where the specific building D&D wells are listed with the reasons for monitoring, analyte list, etc. An appendix perhaps?***

Comment Response (Sec 4.3.2.5):

We agree that a separate appendix should be created for wells in the D&D category, especially if they are to be monitored for a short period of time using temporary wells.

***(13) P.82: RFCA specifies a time frame of 2 years to detect a decreasing trend. Since existing wells are chosen for this whenever possible the travel time from the source to a PM well should be calculated and possibly an estimate of the improvement expected in the contaminant concentration over time would help evaluation of performance. Name the appropriate parties and those responsible for the evaluation.***

Comment Response (Sec 4.3.2.6):

This comment suggests that RFCA sets a 2 year time frame for detecting decreasing trends in Performance Monitoring wells. In fact, RFCA uses this time frame for Tier I exceedances, not for Performance monitoring. Therefore, this time frame does not apply to Performance Monitoring wells.

This comment also suggests that a prediction should be made as to the expected improvement expected for contaminant concentrations in groundwater from an accelerated action. This is not feasible for a soil cleanup where DNAPL is involved because of the inherent uncertainties of DNAPL migration in the subsurface and whether source removal will effect the plume at all. Responses with respect to appropriate parties and responsible organizations have already been covered.

***(14) P.93: What part of this decision is on the well head basis? Add background water level information to input list.***

Comment Response (Sec 4.3.3.1.2):

This decision logic justifies the collection of water level data in the Industrial Area for use in identifying significant changes in the water table. The decision boundaries were written so that a change in a well or group of wells may be of interest as well as groundwater in the Industrial Area as a whole. The decision boundary will be rewritten as follows:

Spatial: Decisions may be made on a well head basis where specific Site activities warrant it, typically decisions will depend on observing changes in the Industrial Area as a whole.

Background water level data will be added to the input list.

***(15) P.94: Are data loggers planned for a few wells to evaluate recharge?***

Comment Response (Sec 4.3.3.1.3):

The use of data loggers has been agreed to for giving information on event related effects on the groundwater table. This will occur in the decision inputs for the Background Flow Monitoring decision as "event monitoring water level measurements". The wells that will be monitored with the data loggers will be listed in the water level table in Appendix E with a daily frequency for measurement.

***(16) P.116: The surface water standards measure total, unfiltered parameters for radionuclides and metals. In order to evaluate the impact to surface water, samples from Tier II wells and any drainage well must be unfiltered. Health risk from all chemicals in ground water is also based on an unfiltered sample, (EPA Risk Assessment Guidance for Superfund, 1989). For these reasons the regular monitoring analysis should be of unfiltered samples. Unfiltered samples collected with low flow sampling devices are acceptable. If other information is desired by DOE from the dissolved portion of the sample it is their option to justify the collection of those samples in the IMP. The samples may be collected if there is suitable sample volume.***

Comment Response (Sec 4.5.1.1):

The comment suggests that since surface water standards measure unfiltered parameters for radionuclides and metals that groundwater should be measured the same way. In fact many of the surface water standards in RFCA require filtered metals analyses. A recent article in the journal 'Groundwater Monitoring and Remediation' (see Saar, Winter, 1997) gives a very good summary of the issues regarding filtered and unfiltered samples, and recommends filtering in most cases. The article makes the case for micropurging, which is presently being implemented on Site. It also suggests that if micropurging is not feasible (which will be true in some RFETS wells) and if comparisons are to be made between micropurged and bailed wells, that filtration should be done. Also, the sample filtration issue for groundwater was presented in the Supplemental Testimony of John Law before the Colorado Water Quality Control Commission meeting of November 26th, 1996. ?

***(17) P.118: Would the plume flux estimate decision rule be acceptable as a revision rather than deemed a rewrite? It is important to define what is necessary for the evaluation of impact to surface water at some point but working out the details may delay approval of this document.***

Comment Response (Sec 4.5):

Section 4.5.1.4 has been added to the text to discuss the evaluation phase of the decision rules. In general, this calculation is part of the evaluation process rather than the only evaluation component. It is assumed that actual field results, whether historic or new data collected as part of the evaluation process will be used to validate the results of modelling. Therefore the decision logic need not be changed. Section 4.5.1.4 will reference the RFCA requirement for modelling impacts to surface water as part of the implementation of the program.

***(18) P.119: The data comparisons listed for the annual report have already been done for the 1996 third quarter report, what level of detail distinguishes the annual report?***

Comment Response (Sec 4.5.1.3.2):

The RFCA final report will compile and synthesize the data published in the RFCA quarterlies and produce a better spatial representation of the data. In addition, the final report will evaluate hydrologic information from water level measurements and document decisions made with respect to evaluations, evaluation results and any changes to the monitoring network.

***(19) P.120: Please support the historic M2SD with plotted trends of historic data. We fail to see the benefit of this number in screening the data.***

Comment Response (Sec 4.5.1.3.2):

This comment again questions the use of the mean plus + 2 standard deviations with respect to historic data as a screening tool. This issue has been discussed in Comment Response #8.

***(20) P.124: It is our understanding that the Sitewide ASAP model was not calibrated successfully. Incorporating the recharge/discharge information gathered on the Site water/waste water systems is critical to understanding ground water flow through contaminated areas of the Site and changes likely to occur during D&D. Maintenance of the modeling capability should be temporary. A modeling team should be formed to assess the modeling needs triggered by existing surface water impacts, new Tier II well exceedances or water level changes noted in monitoring.***

Comment Response (Sec 4.5.1.5):

The ASAP groundwater flow model achieved its goal of attaining level three calibration. Additional calibration work may be required depending on the specific goals or future modelling efforts. The ASAP modelling project was not completed to address monitoring issues, which is why there is no reference to it in the IMP. Data compiled for the ASAP model and for other Site modelling activities could be used in future impact evaluations to support other modelling decisions if deemed appropriate.
Comment Response #2 has already discussed the recharge/discharge issue.

The comment also re-iterates the idea of forming a modelling team to assess modelling needs for impacts to surface water. If numeric modelling is the goal of this team, then it seems too specialized for the evaluations that are envisioned. Evaluations as stated in the updated text can involve field investigation, current and historic data analysis, and the use of analytical solutions to determine impacts to surface water. What will be required is a stakeholder group to take part in the scoping and DQO development of the evaluations, not just numeric modelling. As such, the current groundwater workgroup, which is composed of technical representatives from EPA, DOE, CDPHE and the K-H team seem well suited to be incorporated in these evaluations.

Incidentally, the comment stating that the ASAP model could not be calibrated successfully is inaccurate. The model was initially calibrated and was in the process of final calibration when funding was cut for the project.

Editorial Comments

***(21) P.62: Last sentence add "and prevent adverse impacts to surface water"***

Comment Response (Sec 4.2.2.1):

The text has been amended to include this comment.

***(22) P.68: In list "This data will be used to:" add "to support modeling and other evaluations".***

Comment Response ( Sec 4.3.1):

The text has been amended to include this comment.

***(23) P.69: Add "compliance," in front of etc.***

Comment Response ( Sec 4.3.1):

The text has been amended to include this comment.

***(24) P.73, 75, 77, 79: Add Historic data trend to inputs. Change background reference.***

Comment Response ( Secs 4.3.2.1, 4.3.2.2, 4.3.2.3, 4.3.2.4):

The text has been amended in each of the decision inputs to include this comment.

***(25) P.87: Ground water flow to down gradient habitats. Add historic water level data, meteorologic data to input list.***

Comment Response ( Sec 4.3.3.1):

The text has been amended in the decision inputs to include this comment

***(26) P.94: Replace impacts with "changes in groundwater levels and subsequent surface water impacts": Add meteorologic data to input list.***

Comment Response (Sec 4.3.3.1.3):

The text has been amended in the decision inputs to include this comment. Also, the decision statement has been changed.

***(27) P.96: Replace impacts with "water supply impacts." Add vegetation map, stream gain/loss information, and water use for vegetation types to inputs.***

Comment Response (Sec 4.3.3.2):

The text has been amended in the decision inputs to include this comment. Also, this decision statement has been taken out of the groundwater portion of the IMP for possible inclusion in a Sitewide integration section of the IMP.

***(28) P.119: First bullet, arrange analyses in order of complexity "hydrographs, potentiometric surface maps, and modeling, where appropriate."***

Comment Response (Sec 4.5.1.3.2):

The text has been amended as suggested.

***(29) Replace "will follow the following" with "use the following."***

Comment Response (Sec 4.5.1.3.2):

The text has been amended as suggested.

***(30) P.120: Replace Background UTL with Background M2SD.***

Comment Response (Sec 4.5.1.3.2):

The text was amended in the last update.

**Position Paper**
**Collection of Annual Recharge and Discharge Data**
**for Site Water Balance Modeling at RFETS**

## Introduction

Rocky Mountain Remediation Services, L.L.C. and Kaiser-Hill are currently in the process of finalizing the Rocky Flats Environmental Technology Site (RFETS) Integrated Monitoring Plan (IMP). Recent Colorado Department of Public Health and Environment (CDPHE) review comments concerning the IMP have suggested that the collection of annual groundwater recharge and discharge data should be undertaken as part of an expanded program of groundwater monitoring activities at RFETS. This data would be used to perform site water balance modeling and support the development of a more comprehensive set of groundwater decision rules for evaluations associated with contaminant action level exceedances and potential groundwater plume interaction with surface water. Additionally, the collection of annual data could conceivably permit a more detailed analysis of the long-term hydrologic impacts associated with plant closure.

This paper serves to evaluate the feasibility of collecting annual field recharge and discharge data for site water balance modeling in consideration of site conditions and available field measurement technology. Descriptions of site conditions that control and affect recharge and discharge measurement are presented as a basis for the evaluation. Brief discussions of previous site attempts at evaluating these parameters are also presented together with an assessment of project success and cost, where available.

## Discussion

In concept, the collection of annual recharge and discharge data is a worthy goal that could permit a more quantitative analysis of changes in the hydrologic budget during and after plant closure. These data are important components of water balance and groundwater modeling calculations that are normally used to help understand how hydrologic systems work. Current information on recharge and discharge at RFETS tends to be more qualitative rather than quantitative. Several field approaches for estimating natural recharge and discharge are available in the literature which, under favorable circumstances, are capable of providing quantitative values for use in hydrologic calculations.

RFETS recognizes the value of annual recharge and discharge data and agrees that such data, if obtainable, could lead to improvements in predicting the impacts of plant closure on the local hydrologic environment. There are, however, some potentially serious technical obstacles that effectively limit or prevent the collection of meaningful field recharge and discharge data at the site. These obstacles include such well-known limitations as the overall geologic and hydrogeologic complexity of alluvial and underlying bedrock deposits, which can profoundly affect the uniformity of recharge and discharge at the site, and the likelihood that artificial sources of recharge (i.e., leaking pipes, unlined drainage ditches, etc.) and discharge (footing drains, sumps, etc.) have significantly altered the local hydrologic regime. Some lesser known obstacles involve the impracticality of installing recharge and discharge monitoring systems in the Rocky Flats Alluvium and attendant limitations with respect to the accuracy and completeness of data collection efforts.

Previous groundwater flow modeling efforts have relied on measured values of potentiometric head, saturated thickness and hydraulic conductivity, and estimated values of recharge and porosity to simulate flow patterns and estimate fluxes. This approach is a common industry practice that is necessitated by the relative difficulty and cost of measuring groundwater recharge and discharge compared to head and hydraulic conductivity in most hydrogeologic systems. Professional judgement is exercised by the modeler in calibrating the hydraulic head distribution of the model using recharge estimates and hydraulic conductivity measurements. At RFETS, annual mean recharge has been estimated to range from 1.0 to 1.2 inches/year based on the results of site-wide and site-specific (OU2) groundwater flow modeling (Roberts, 1996). This range is considered to be reasonable given the climate and hydrogeologic setting of the plant site, and provides a basis for future modeling efforts.

A brief discussion of issues related to recharge and discharge measurement in the Rocky Flats Alluvium are provided separately below.

**Recharge**

In recent years, RFETS contractor and subcontractor personnel have both formally and informally evaluated the technical feasibility of collecting recharge data for various modeling and monitoring applications. Aside from unsaturated zone actinide transport research activities conducted at the 903 Pad hillside soil monitoring system site, several evaluations were conducted as part of the Zero-Offsite Water-Discharge Study (ASI, 1991 a, b, and c). This study focused on a variety of recharge and discharge-related subjects, including sanitary and storm sewer infiltration/exfiltration, leakage detection monitoring of water supply pipes, and recharge in native soils.

*Native Soils*

EG&G initiated a field recharge study at two locations in the East Trenches area in 1993 to quantify recharge fluxes for the OU2 and site-wide groundwater modeling applications (ASI, 1993). This study was the outgrowth of recommendations made by ASI during the Zero-Offsite Water-Discharge Study. These monitoring systems were designed with the assumption that diffuse recharge was the dominant recharge mechanism operating at the site, with diffuse recharge being approximately equal to total natural recharge. Monitoring equipment consisting of a multiple tension lysimeter and neutron access tube arrangements were employed to monitor wetting fronts moving through the soil profile. Shortly after monitoring was begun, it became increasingly apparent that soil macropores played a much larger role in facilitating recharge than previously assumed, as indicated by preliminary results reported by M. Z. Litaor from the 903 Pad hillside soil monitoring site; consideration of the rapid water table responses observed in many alluvial wells shortly following major spring precipitation events; and some then-recent articles in the published literature. The project was subsequently terminated voluntarily for technical reasons by agreement among the EG&G field and modeling investigators, because it had become apparent that total natural recharge would be significantly underestimated using this methodology.

The apparent dominance of soil macropore control on infiltration indicates that total recharge would be an extremely difficult field parameter to accurately measure for the Rocky Flats Alluvium. This conclusion is based on consideration of the design and installation problems that would be associated with monitoring a representative volume of predominently coarse-grained, heterogeneous, and macroporous alluvial soil material in an undisturbed state. Installation of "undisturbed" samplers, such as zero tension lysimeters, used in the instrumented trench wall approach at the 903 Pad hillside soil monitoring site would be very difficult, if not impossible, due to the rocky nature of the Rocky Flats Alluvium. The 903 Pad hillside soil monitoring site could be used for recharge monitoring, but is situated in colluvium at a groundwater discharge area located outside the boundary of the Rocky Flats Alluvium. It would, therefore, be inappropriate and misleading to generate recharge data from this site and apply it to the Rocky Flats Alluvium, which has an entirely different soil texture, structure, permeability distribution, and vegetative cover. Construction of large box-type lysimeters used in agricultural research could also be employed, but would involve destruction of the existing soil structure, which would defeat the purpose of the study.

Various chemical and environmental isotopic methods are also available for quantitatively estimating recharge; however, these methods only work in relatively ideal geographic and geologic settings, and yield only a long term average value. Chemical methods for estimating recharge, such as chloride, would not work at RFETS because past and current plant operations and urban expansion, in general, have significantly altered the chloride content of the local groundwater and atmosphere. Isotopic approaches to estimating recharge, such as the tritium bomb pulse method, can not be applied because the presence of detectable tritium in background groundwater indicates that the bomb pulse has already passed through the soil profile.

*Industrial Area*

In the Industrial Area, the groundwater recharge regime is expected to be highly altered and complex due to the patchwork presence of buildings, paved and unpaved areas, roads, drainage ditches, buried utility lines, and other surface and subsurface features. Of particular interest is the extensive network of buried utility lines that traverse the Industrial Area, including shallow electrical, gas and communications line systems, and deeper sanitary sewer, storm sewer, foundation drain, and water line systems. According to the Zero-Offsite Water-Discharge Study (ASI, 1991 a, b, and c), there are an estimated 200,000 feet (38 miles) of water, sanitary sewer, and storm sewer pipe alone installed mainly within an area measuring approximately 7,000 feet in length and 3,200 feet in width. Buried water and waste water lines have been implicated as potential sources of recharge water due to the potentially leaky nature of aging, pressurized and unpressurized pipe systems (ASI, 1991 a, b, and c), sometimes with both recharge and discharge occurring at different points within the same system (i.e., sanitary sewers). Recharge variability at the surface is also expected to be high, where impermeable areas comprise a significant portion of the total surface area and drainage ditches concentrate runoff below original grade.

*Spatial Variability*

Spatial variability in recharge is an inherent characteristic of any geologic deposit. Natural recharge for the Rocky Flats Alluvium is implied to be highly variable, as indicated from observed lateral discontinuities in caliche content and soil types; nonuniform patterns of upland vegetation; differences in well responses in undisturbed areas of the site; and the five order-of-magnitude range of saturated hydraulic conductivities measured across the site. The spatial complexity of the natural recharge distribution is intuitively too great to be monitored at a single locality and would likely require numerous localities to obtain a representative site-wide value.

By far the greatest potential for spatial variability occurs within the Industrial Area. The presence of impermeable areas, buried water and wastewater lines, ditches, and plant operations practices (i.e., snow removal and storage) all greatly complicate an understanding of the local recharge regime. Pipe and ditch losses are thought to be areally significant, but recharge from these sources is typically obscure and unmeasurable. Local areas of high recharge (runoff concentrated on areas of native soil) are expected to occur next to areas of little or no recharge (paved areas). Considering the potential number, type, and location of point and non-point recharge sources that exist in the Industrial Area, it would clearly involve a major undertaking and expense to measure annual recharge, even if simplifying assumptions are made about pipe and ditch loss estimates.

Collectively, the difficulty associated with obtaining representative field recharge measurements and spatial complexity of the site indicate that a large degree of uncertainty will be associated with any total annual recharge measurement attempted at the plant. For these reasons, we have concluded that field measurement of total annual recharge at RFETS is essentially an intractable problem that is better estimated using numerical groundwater modeling techniques.

## Discharge

For the purposes of this discussion, groundwater discharge at RFETS has been broken down into four primary components: 1) subsurface discharge (interformation flow and vertical leakage), 2) evapotranspiration, 3) seep flow, and 4) industrial outflow. Each component will be reviewed briefly with respect to existing site conditions and feasibility of measurement.

### *Subsurface Discharge*

Measurement of subsurface discharge is, in many respects, just as difficult and ambiguous a parameter to estimate as recharge. Subsurface discharge is necessarily estimated rather than measured because of the obscurity and three-dimensional nature of groundwater flow. Lateral flow can sometimes be concentrated and conveyed to a discharge collection and measurement structure, but there is no field method available for the direct measurement of uncontrolled subsurface discharge. The accuracy of the estimate will depend on such factors as the accuracy and completeness of the input data and uniformity of subsurface conditions. As more accurate estimates of discharge become necessary, the data requirements begin to escalate as dictated by the complexity of the hydrogeologic setting.

The hydrogeology of the fan margin and bordering hillslopes is arguably the most complex and least understood region at RFETS. Abrupt spatial variations in alluvial saturated thickness and hydraulic conductivity are common and are often unpredictable. Near the eastern fan margin, groundwater flow tends to concentrate along bedrock lows, forming an irregularly saturated, and sometimes discontinuous, subcrop zone with the adjoining geologic deposits. Subcropping, discontinuous permeable sandstone beds, which derive water from the overlying alluvium, are also known to discharge along hillsides in some areas as seeps. The hydrologic complexity of hillslope areas is well documented from detailed drilling programs conducted as part of the 881 Hillside and OU5 remedial investigations.

Presently, well coverage of the fan margin at the industrial area is adequate for plume monitoring and preliminary groundwater flux estimates. Improved well coverage may be required to refine groundwater flux estimates in certain circumstances (i.e., groundwater plumes potentially impacting surface water), but a site-wide effort to more accurately estimate discharge would involve a substantial investment in new well coverage and monitoring. This investment does not appear to be justified at the current time because threats to surface water are limited to individual plumes, not from all groundwater discharging from the site. It is expected that evaluations of individual plumes, using a range of potential input parameter estimates, will adequately assess the potential impact of plume contaminants on surface water quality.

*Evapotranspiration*

Evapotranspiration (ET) of groundwater is limited to seeps, stream channel alluvium, and other areas of shallow, nonemergent groundwater flow. Riparian vegetation has been shown to be a significant source of groundwater discharge, occurring mainly during the active growing season. ET is highly influenced by local site conditions, including climate, vegetation, aspect, air temperature and humidity, depth to water, and other factors. At RFETS, the role of ET as a locally significant groundwater discharge mechanism is apparent from well hydrograph trends for wells completed in stream channel alluvium which show seasonal lows during the summer months.

Previous ET measurement at RFETS has not been attempted, in part, because environmental restoration activities have focused on characterization and remediation rather water balance and ecological issues. In addition, field measurement of ET is a notably laborious, difficult, and costly process, requiring the construction of box lysimeters or other devices; operation of monitoring equipment for measuring soil, water, and atmospheric conditions; and analysis and interpretation of the collected data. The analysis is further complicated by the fact that every seep is a unique habitat that will vary in ET output. Estimation of ET groundwater discharge from analysis of daily hydrograph responses might be possible for stream channel alluvium, but would not be applicable to hillside seepage areas. For seeps, it might be possible to prepare an order-of-magnitude estimate ET using published phreatophyte water consumption and local climatologic data for use in water balance calculations. This approach, however, would provide only a rough idea of ET and might not be meaningful for site water balance modeling. The difficulty involved with measuring and estimating ET adds further uncertainty into any analysis performed using a site water balance model.

*Seepage Flow*

Surface discharge from seeps with channelized flow is easily measured using standard methods. On the other hand, seeps with diffuse or sheet flow characteristics can be extremely difficult to measure without creating adverse impacts to the ecology of the seep. In either case, traditional seep flow measurement involves only the surface component of the total discharge at the seep. This data has a limited value because the total amount of groundwater discharged to the stream drainage from the seep, which is normally the parameter of interest in water balance and mass loading calculations, is substantially underestimated. Few seeps in the Industrial Area discharge directly to surface water and, of those, most flow ephemerally.

Measurement of coupled surface and subsurface discharge would be necessary to determine the total flow at each seep. This arrangement was previously considered by EG&G for a possible field research study with the University of Colorado-Boulder, but was later dropped for cost reasons. The total burdened cost of the project, including

EG&G oversight, was estimated at $370K for fiscal year 1992. This cost, while ostensively high, reflects the level of difficulty involved with designing, installing, and operating a monitoring system for obtaining accurate measurements of seep flow in a minimally disturbed field setting. When considering the geologic setting of most seepage sites (i.e., landslide deposits), the only practical alternative to a heavily instrumented and well characterized seep is the direct measurement of seep flow using a funnel-and-gate system or similiar collection device. The cost of such a system would be unacceptably high and would cause irreparable damage to the habitat of the seep. Cumulatively, the cost of monitoring multiple seep complexes using any of the available methods would be clearly prohibitive.

*Industrial Outflows*

As mentioned previously, an extensive system of sanitary and storm sewer lines installed in the Industrial Area is suspected of receiving and discharging infiltrated groundwater (ASI, 1991a and b), together with flows from industrial sources. Interspersed with these systems are additional networks of individual building foundation drains, french drains, tunnels, and other subsurface conveyances of undetermined length that collect groundwater for treatment or drainage purposes.

With few exceptions, industrial outflows consist of admixtures from a variety of sources. The sanitary sewer system is known to receive flow from roof drains and catchment basins. The storm sewer receives flows from building foundation drains. To determine the groundwater discharge associated with these systems, the other sources would have to be quantified and subtracted from the total discharge. While it would be possible to measure discharge at all the industrial outflows on site, there is currently no means for differentiating the groundwater component of sanitary and storm sewer flows, which will vary with time due to cycles in industrial activity, precipitation events, groundwater levels, and other factors. This limitation places another significant uncertainty into the site water balance approach.

**Conclusions**

In summary, there are simply too many variables and unknowns involved with measuring or estimating groundwater recharge and discharge at RFETS to justify an enhanced characterization and monitoring program for site water balance determinations. The difficulty of measuring or estimating such a large number of sites and parameters calls into question the practicality of using a site-wide water balance model for assessing the quantitative impact of specific plumes on surface water quality and decision making in general. Any effort to improve the reliability of the input parameter estimates is controlled and limited by the complexity of the hydrogeologic and industrial environment. Implementation of an enhanced site-wide groundwater recharge and discharge characterization and monitoring program would involve a considerable expense and diversion of resources from other risk reducing, environmental restoration projects. In some cases, the collection of field data is clearly technically infeasible.

For these reasons, we believe that plume evaluations and models based on the available types of data provide for manageable and cost effective analyses of potential impacts to surface water quality. The collection of additional field data is not expected to result in an appeciable improvement in model reliability. Reliance on professional judgement in estimating parameters, such as recharge, for modeling efforts is adequate for remediation decision making, given the limitations and costs of measuring recharge and discharge.

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